THE UNIVERSITY OF ALBERTA

FLEXIBILITY TRAINING: THE OPTIMAL TIME PERIOD TO SPEND IN A POSITION OF MAXIMAL STRETCH

BY

© RICHARD ALAN BATES

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Flexibility Training: the Optimal Time Period to Spend in a Position of Maximal Stretch" submitted by Richard Alan Bates in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

Thirty male Physical Education students, average age 24.4 years, were blocked into six treatment conditions of five subjects each and trained in a position of maximal stretch (the side splits). Each subject was assigned to hold the maximal stretch position for one of the following time periods on each training day, five days a week, over a period of three weeks: zero, ten, thirty, sixty, ninety, or 120 seconds. Individual flexibility scores were recorded on a pre-test, after one, two, and three weeks of training, and three weeks later with no intervening training.

The following three hypotheses were tested for significance at the 0.01 level of probability and were rejected.

1. There is no difference in flexibility gains as a result of the increasing time a side splits position is held.

2. There is no difference in the retention of flexibility gains between groups maintaining a side splits position for increasing lengths of time.

3. There is no difference in the rate of gaining flexibility as a result of the increasing time a side splits position is held.

It was found that the group of subjects using sixty seconds of training to increase flexibility gained more flexibility, retained more flexibility, and gained flexibility faster. It was also found that by taking initial level of flexibility into account sixty seconds of training produced a greater increase in flexibility over any other group for those low, low-average, average, and high-average in initial flexibility. For those high in initial flexibility there

[illegible]

was no significant difference between the gains produced by thirty or sixty seconds of training.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Flexibility is most obviously used in gymnastics. Since the writer has been involved with gymnastics of this type for a number of years, flexibility training has been a major consideration. More specifically, gymnasts are interested in flexibility of the hip region, that is, side splits, regular splits, and straddle sit with trunk flexion.

Many training techniques are employed, for varying time lengths, in order to achieve the desired result of increased flexibility. Most gymnasts and gymnastics coaches are aware of the dangers involved in using a dynamic stretch (33) to increase flexibility; thus this technique is rarely used. The best results appear to be obtained using a static stretch technique (9, 10, 12) or a slow stretch with a light springing motion at the end of the range of movement (33); conscious relaxation aiding in gaining flexibility. The theory behind the techniques used, therefore, is similar; only the body position is adjusted in an attempt to achieve faster or more lasting results or to work different angles of the joint's range of motion.

However, what remains dissimilar and lacks experimental proof, is the actual time length spent in these varying positions. For example, how long should you maintain a regular splits position in order to achieve a desirable effect: ten, thirty, or sixty

seconds? Modern Gymnast magasine (30) recommends that a splits position be held for eight to ten seconds, but DeVries (12) recommends that a maximal stretch position be held for one to two minutes.

It would be of great practical value to experimentally determine whether the actual time spent in a position of stretch has an effect on increasing flexibility, developing it faster, or in maintaining it longer. However, it must be remembered that it has been adequately demonstrated by Harris (24) and by Dickinson (13) that the different motions possible at a joint are independent phenomena. Thus the results obtained from the specific flexibility skill studied in this thesis may not apply to other joint motions, without empirical testing.

The Problem

The purpose of this study was to investigate what effect time actually spent in a position of maximal stretch would have on improvement of flexibility. The problem under investigation was whether the flexibility of male Physical Education students would increase as the time spent in a side splits position varied from ten seconds to 120 seconds.

The Hypotheses

Since the statistical model that was used to analyze the data was based on the null hypothesis, the following hypotheses were stated and were tested at the 0.01 level of probability.

1. There is no difference in flexibility gains as a result

of the increasing time a side splits position is held.

2. There is no difference in the retention of flexibility gains between groups maintaining a side splits position for increasing lengths of time.

3. There is no difference in the rate of gaining flexibility as a result of the increasing time a side splits position is held.

Limitations

1. The experimenter had no control over his subjects, except during the testing situation, and thus could not eliminate other activities which may have affected flexibility training.

2. The experimenter could not control the subjects' motivation to relax or to endure some discomfort in training for the side splits.

3. A support was provided for balance in the side splits position and for maintaining the correct posture; however, it was difficult to control the exact amount of pressure exerted on the support by each subject.

Delimitations

1. The subjects used were thirty volunteer Physical Education males at the University of Alberta, and thus inferences to other populations are questionable.

2. The experiment was limited to one flexibility action only, the side splits, and thus the results obtained should not be applied to other flexibility skills.

3. The experiment was also limited by the fact that only one training technique was used for varying time lengths, and thus conclusions should not be applied to other techniques until empirical proof is available.

4. All subjects were not exposed to the splits position for the same amount of total time.

Definition of Terms

Flexibility. Flexibility is defined as the range of motion in a joint. Thus an increase in flexibility is an increase in the range of motion.

Flexibility Gains. The increase in range of motion, as a result of flexibility training, over and above the initial range of motion, as measured in degrees on a Leighton flexometer (32).

Retention of Flexibility. The ability to maintain the range of motion achieved after a period of flexibility training.

Side Splits. With the trunk held in an upright position and facing forward, the legs are slowly abducted to a position of maximal stretch. Ideally, the legs should rest on the floor, that is, 180 degrees apart.

Total Time Spent in a Side Splits Position. The total time spent in a side splits position is the sum of the time spent each day in the splits position over the entire number of days spent in training, for example, ten seconds multiplied by fifteen days.

Actual Time Spent in a Side Splits Position. The actual time spent in a side splits position is the length of time a side splits position was maintained on one training day, for example,

ten seconds.

CHAPTER II

REVIEW OF THE LITERATURE

Nature of Flexibility

Flexibility has been defined as the capacity to bend, be flexed, or extended without breaking (7) or technically, as the measurement of range of motion in the joints (26). However, there is a problem with the term flexibility under these frequently used definitions. It has been adequately demonstrated by Harris (24), who performed a factor analysis on flexibility measures and found that each possible joint action was uncorrelated to any other joint action, and by Dickinson (13), who found very low correlations of joint movements, that the different motions possible at a joint are independent phenomena. It was suggested by these authors that flexion and extension, for example, should not be used as a combined measure of one thing, wrist flexibility.

This high degree of specificity of flexibility is in direct contrast to the long held notion of the generality of flexibility and indicates the need for research into the anatomical and physiological factors of joint mobility. Billig (3) felt that the ligaments determined the range of motion. In fact, shortening of the elastic phase of the ligaments due to age, inactivity after a period of activity, tearing, disease, or temperature changes offered us the best reason for including flexibility training in all our activity programs. However, Johns (29) found that the ligaments play a minor role (10%) in joint stiffness, except at the very extremes of joint positions. The joint capsule and the musculature

accounted for the major portion of mid-range stiffness (85%), while viscosity contributed only 2% to the total stiffness (an important concept to consider in the relationship of warmup and flexibility).

Measurement Techniques

Flexibility measures of some years ago used trunk flexion and extension as an indication of the individual's flexibility. For example, the Wells Sit-and-Reach test (43) had the subject sit with the legs straight and reach with the hands for the toes. Besides the inaccuracy of a linear measure for an angular motion, the angle at the shoulder joint and the flexed position of the foot greatly confused the results. This was borne out by the poor correlation between Leighton's flexometer test (32) and the Wells Sit-and-Reach.

Thus, the concept of a linear measurement for flexibility is inaccurate and should be replaced with the concept that flexibility is an angular motion and should be measured as such. In addition, Hall pointed out (23) that flexibility measures should use standardized techniques so that the results can be compared and second, norms of flexibility should be developed on a large number of subjects so that defects or disease can be detected or recovery can be aided. In these regards, Leighton (32) devised an instrument (which is an angular measure) and a standardized technique for measuring flexibility.

Other researchers had previously attempted to devise an instrument but with limited success. Wilmer (45) working on the supposition that movement of the joint occurs about a specific point, realized that mechanical goniometers might incorporate a significant

error and devised an optical goniometer held in one hand, sighting the angle of the joint movement on its scale. Zankel further reasoned that unless this optical goniometer was held at ninety degrees to the plane of the joint being sighted, large errors would occur. He constucted a device (47) to project a scale onto the joint for measurement, the projector being adjustable to achieve a plane perpendicular to the one being measured.

Very few studies have studied the normal range of motion in different joints of large numbers of people. Leighton (32) in developing his instrument tested fifty-six college students on fourteen flexibility movements. Of particular interest to this study was the fact that he found abduction of the left leg to average 54.6 degrees with a standard deviation of 7.8 degrees.

Relationship of Flexibility to Other Variables

Morphology. Several researchers have investigated the relationship between body somatotype and flexibility or length of body segments and flexibility. These investigations tested the beliefs that if arm length or arm length plus trunk length were greater than leg length then performance of a trunk flexibility test would be much improved, and that if you were of a certain body type then you would be more or less flexible than someone of a different somatotype.

Mathews (35) with young boys and again with college women (36) found that no significant relationship exists between hip-trunk flexibility and the length of body segments. Harvey (25) in testing college women found no relationship even with the extreme

groups of women. It should be pointed out that the above tests were carried out using a sit-and-reach type test which has been previously discussed as being inaccurate as a measure of hip-trunk flexibility.

McConville (37) found in measuring college males that no correlation exists between anthropometric measures or somatotype and hip-trunk flexibility. However, Tyrance (41) measured the extremes of body types only, and found a significant difference in their flexibility, specifically their neck, overall hip flexibility, and their knee and elbow flexion. He also found that as mesomorphy increased neck flexibility increased.

This last point brings up a commonly held notion that weight-lifters are inflexible or "muscle-bound". Massey (34) pointed out in his research that champion weight-lifters are well above average in flexibility and he found that the only cases of inflexibility of weight-lifters occurred where an imbalance of developing exercises was used. Thus it seems that the concept of the balancing of muscle strength about a joint determines flexibility to a great extent.

<u>Warmup and Performance</u>. Many factors affect performance besides flexibility; with one of these factors, namely warmup, there is some confusion since a warmup may consist of stretching exercises. By the relationship of warmup to flexibility is implied simply the heating or warming effect on flexibility.

Only one study could be found relating warmup or heat to flexibility, that of Badgley (2). She tested the increase in flexibil- of the ankle as a result of different times of whirlpool treatment and found significant increases as the time increased. She postulated

that raising the temperature of the joint would increase its range of motion. However, her study is particularly weak in that it did not measure whether the increase in flexibility was maintained. It seems that her study would be useful for healing an injured joint or restoring flexibility, but without knowledge of the retention of flexibility the study would be of little value for those interested in increasing their flexibility. Buchtal (4) found that as temperature fell muscle stiffness contributed more to contraction tension and thus to inflexibility, implying that heat would have improved flexibility.

Carlile (6) using hot showers to passively heat swimmers found a significantly improved performance but attempted no explanation of why this occurred. Thus we might have assumed that it incresed the swimmers' flexibility. However, Asmussen (1) showed that it was the increase in local muscle temperature which accounted for a greater absorption of oxygen by the muscles and not an increase in viscosity as Buchtal suggested or not an increase in elasticity as we might have surmised that accounted for the improved performance.

Performance enhanced by increased flexibility is an assumption which many coaches have operated under and one which has been tested very little. Davies (8), looking at the negative side, found that postural divergencies (which were thought of as resulting from inflexibility as well as muscle imbalance) did not inhibit a child's performance in motor activities. DeVries (11) isolated the factor of flexibility to see what effect improvement of flexibility (using warm-up exercises) had on running times for a 100 yard dash, and found no significant improvement in times. It is doubtful therefore that warm-

up increases flexibility and thus improves performance.

Training Techniques

Research in training for flexibility has centered around the type of stretch to be engaged in, that is, fast (dynamic and to a lesser extent, active stretch) or slow stretch (static stretch). Logan (33) reported a 200% increase in flexibility with the use of a slight spring stretch at the end of the range of motion (active stretch) and no difference between fast and slow methods of improving flexibility, except that the fast method produced pain. Fieldman (17) found that as the exercises became more active, related to the activity, there was more of an increase in flexibility. This implied that speed of movement would overcome a good deal of the resistance to stretch (although risking injury). Buchtal (4) would argue with this based on his findings that tension stiffness and dynamic shortening of the muscle increased as the strength of the stretch stimulii increased.

DeVries (12) used Buchtal's findings and further postulated that there was a limit to the extensibility of the tissues, and that fast stretching had a higher energy requirement. He thus came to the coclusion that a slow or static stretch would be better. He first proved (12) that there was no difference between fast and static stretching in improving flexibility, and then used an electromyograph to record the resting muscle potentials before and after stretch (9). The difference in activity was very significantly lower than before stretch. As many of his studies included subjects who were athletes with stiff muscles, he came up with the further opinion that static

stretching as a result of reducing the muscle action potential would be effective in preventing muscular soreness not in just relieving it. This he tested (10) and found true.

To effectively increase flexibility DeVries (12) stated that a position of stretch must be maintained for a period of time (one to two minutes). He suggested no reasons why nor did he support with evidence the length of time necessary. No other researchers have made any mention of a time factor in training for flexibility.

CHAPTER III

METHODS

Subjects

The sample used in this study consisted of thirty male students enrolled in Physical Education at the University of Alberta. The subjects were volunteers, between the ages of eighteen and thirty-eight inclusive. Volunteers who could perform the side splits or had previously been able to do the side splits were not permitted to participate in the study, nor were those directly engaged in flexibility training of this type at some other time. All subjects were pre-tested and ranked according to their range of motion in performing the side splits. To overcome differences in initial flexibility, the subjects were divided, on the basis of their initial flexibility, into five blocks of six subjects. The subjects in each block were then randomly assigned to one of the six treatment conditions (15, p.159).

Time and Duration of the Study

All training was performed from 9:00 a.m. to 4:00 p.m., Monday to Friday, during a three week period at the University of Alberta. Pre-testing was performed prior to the training period. The test for retention of flexibility was performed three weeks after the conclusion of the training period.

Materials

The materials and equipment used in this study were: (1) one Leighton flexometer, strapped to the back of the thigh of the

left leg to measure the degrees of abduction; (2) a smooth surfaced tiled floor with a measuring scale marked in inches for performing the side splits; (3) a one and one half inch diameter pole, fixed in position, for balance and support in the side splits; and (4) a stopwatch.

Experimental Design

A 6x5x5 factorial design, fixed effects model, was used with one observation per cell; thus requiring a total of thirty subjects for the six experimental treatment conditions (figure 1). A single control group was incorporated, containing five subjects, as one of the treatment conditions. This type of design was chosen because it enables one to examine all possible interaction effects and to investigate the effects of numerous treatment conditions while maintaining a relatively small sample size (15).

The treatment conditions were the various time periods spent in a side splits position on one training day, and the dependent variables were the five measures of flexibility given at different times, and the subject's level of flexibility. The different time periods spent in the side splits position on one training day were: ten, thirty, sixty, ninety, and 120 seconds. Each treatment condition had five subjects assigned to it and each subject was tested five times: a pre-test, after one week of training, after two weeks of training, after three weeks of training, and three weeks after this last test with no intervening training.

Test Procedures

All subjects, including controls, were dressed alike:

Figure 1:

Schematic Diagram of Experimental Design

A- Treatment   B- Time   C- Blocks (level of flexibility)

A- Treatment	C- Blocks	B_1 Initial	B_2 1 wk.	B_3 2 wk.	B_4 3 wk.	B_5 Retention
A_1 Control	C_1 High C_2 C_3 Average C_4 C_5 Low					
A_2 Ten Seconds	C_1 High C_2 C_3 Average C_4 C_5 Low					
A_3 Thirty Seconds	C_1 High C_2 C_3 Average C_4 C_5 Low					
A_4 Sixty Seconds	C_1 High C_2 C_3 Average C_4 C_5 Low					
A_5 Ninety Seconds	C_1 High C_2 C_3 Average C_4 C_5 Low					
A_6 120 Seconds	C_1 High C_2 C_3 Average C_4 C_5 Low					

bikini-type swimming trunks and a pair of thick wool socks to facilitate training for the side splits and testing (Appendix 1). All subjects received identical instructions on the method to be used in training for the side splits prior to the pre-test, the first day of training, and otherwise as required during training (Appendix 2).

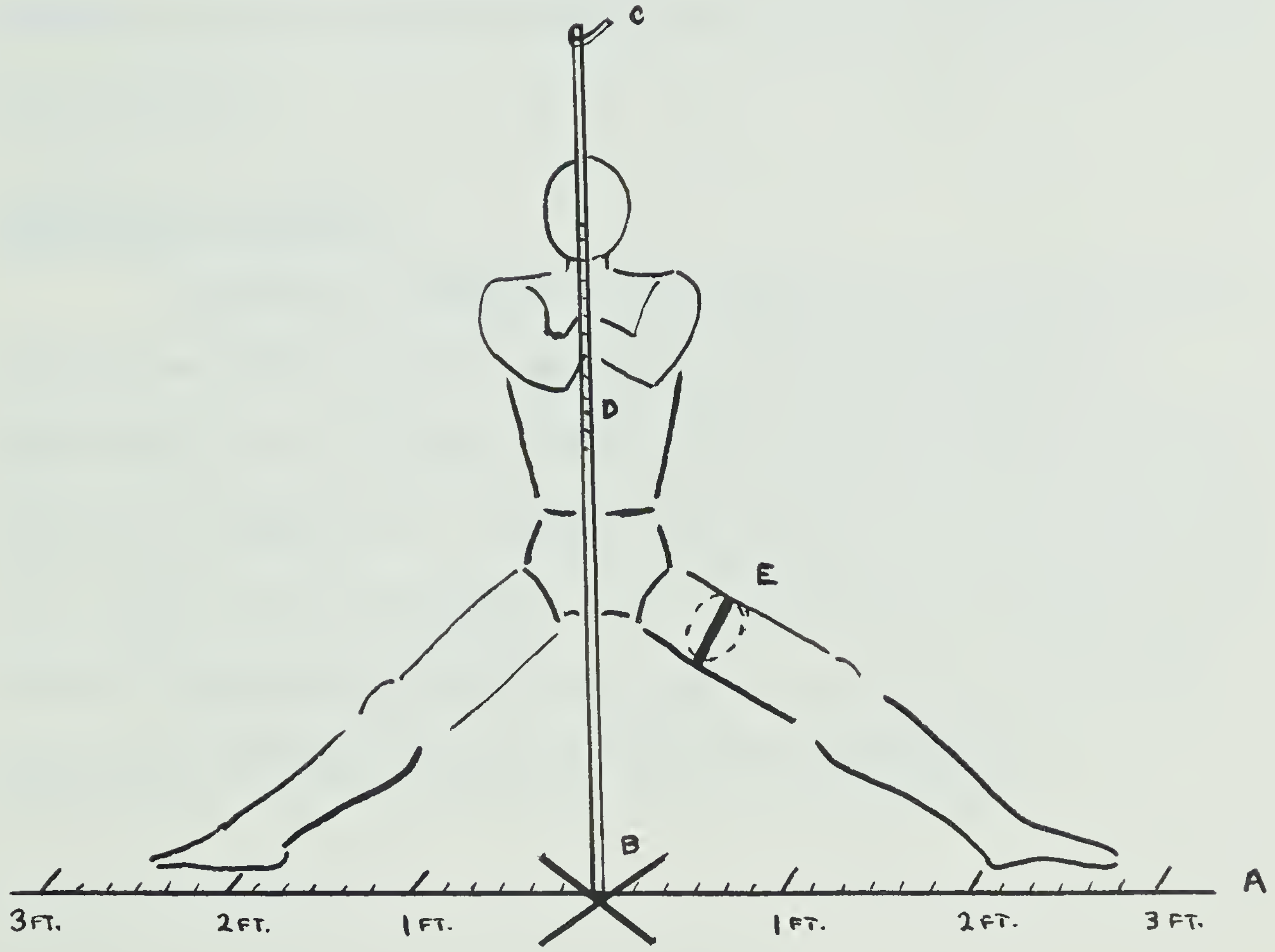
Each subject assumed the splits position according to instructions and held it for the required length of time. The only difference with the control group came at this point; they were not required to report each day; they were required to come only for the testing days.

No warmup was used for any subject on any training day in order to isolate the effectiveness of the training procedure in improving flexibility. Thus each subject was required to assume the side splits position only once for the required time length on each training day. To ensure the subjects stretched maximally each day, a scale marked in inches was placed on the floor for reference (figure 2).

Every subject was pre-tested and informed generally of what would be expected of him during the experimental period. The pre-test was identical to the three tests during training and the test for retention. A Leighton flexometer was strapped to the left thigh of the subject while standing. With the legs together and vertical (toes pointing out at forty-five degrees) the flexometer was set to zero degrees. The subject slowly assumed a position of maximal stretch (following the instructions of a normal training day) at which point the reading in degrees was taken from the

Figure 2:

Equipment Used in the Study



(A) Scale marked in inches, acts as guide for toes

(B) Pole supported at its base

(C) Pole supported at its top

(D) Pole taped for hand grip

(E) Leighton flexometer attached to back of left thigh

flexometer.

Each subject was required to come five days a week to train for the side splits, for a period of three weeks. On the last day of each week the subjects were tested as in the pre-test. The test for retention was performed three weeks after the last training day. The procedure followed was exactly that of the pre-test situation.

Statistical Treatment

A three-way analysis of variance (40, p.124) was used to analyze the data collected and test the three hypotheses. A Newman-Keuls test for simple main effects (46, p.309) was used to isolate the significant treatment conditions. The three hypotheses were tested for significance at the 0.01 level of probability. To further illustrate the third hypothesis, increase in flexibility versus time for each treatment condition was graphed.

CHAPTER IV

RESULTS

Subjects were ranked according to their level of flexibility and then divided into five blocks of six each; each subject then being randomly assigned to one of the six treatment conditions (Appendix 3). During the three weeks of training the subjects' scores were recorded at the end of each week; and after three weeks of no training a final score was obtained (Table 1).

A three-way analysis of variance (40, p.124) was performed on the results in Table 1 to determine the significance of the results. These results are presented in Table 2, the 0.01 level of probability being chosen for the F ratios. On the basis of these F ratios the first hypothesis was rejected.

Having obtained a significant A, B, C, AB, and AC the results were graphed to help in determining which results warranted further testing (Figures 3, 4, 5, and 6), and in deciding whether to accept or reject the second and third hypotheses.

Since it had been decided to use a Newman-Keuls test (46, p. 309) for significant differences between means and, with the aid of the graphs, it was decided to test differences between all levels of treatment conditions at each level of time, all levels of time at each level of the treatment conditions, and all levels of treatment conditions at each level of initial flexibility, it was necessary to obtain the square of the error term at each of these levels (Appendix 4). Thus $S_{\bar{x}}$ was calculated and also a table of $S_{\bar{x}}q.01(r_{2-6}, d.f._{error})$ for each of these levels (Appendix 5).

Tables of differences between means at each level were constructed and tested for significance against the critical values of $S_{\bar{x}}q_{.01}(r_{2-6}, d.f._{error})$, (Tables 3, 4, and 5). On the basis of these comparisons the second and third hypotheses were rejected and additional support for rejection of the first hypothesis was given.

Table 1: Flexibility Scores (Degrees)

Block	Treatment	Subject	B1 Initial	B2 1 wk.	B3 2 wk.	B4 3 wk.	B5 Retention	Average
C_1 High		5	52.0	48.0	48.0	50.0	50.0	49.6
C_2	A_1	8	48.0	46.0	49.0	48.0	46.0	47.4
C_3	Control	13	45.0	46.0	46.5	46.0	44.0	45.5
C_4		19	42.0	42.0	44.0	44.0	42.0	42.8
C_5 Low		30	29.5	28.0	30.0	30.5	29.5	29.5
	Average		43.3	42.0	43.5	43.7	42.3	
C_1		4	53.0	50.0	53.0	54.0	52.0	52.4
C_2	A_2	10	46.0	42.0	47.5	50.0	46.0	46.3
C_3	Ten	17	42.0	38.0	45.5	49.0	46.0	44.1
C_4	Seconds	23	40.0	42.0	43.0	43.0	40.0	41.6
C_5		26	36.0	37.5	38.5	40.0	37.0	37.8
	Average		43.4	41.9	45.5	47.2	44.2	
C_1		3	53.0	55.0	58.0	62.0	55.0	56.6
C_2	A_3	11	45.0	46.5	50.0	52.0	50.0	48.7
C_3	Thirty	18	42.0	45.0	50.0	55.0	55.0	49.4
C_4	Seconds	22	40.0	43.0	43.0	45.0	40.0	42.2
C_5		29	36.0	40.0	40.5	42.0	40.0	39.7
	Average		43.2	45.9	48.3	51.2	48.0	
C_1		2	54.0	56.0	56.5	58.0	56.0	56.1
C_2	A_4	9	47.5	50.0	54.0	59.0	54.0	52.9
C_3	Sixty	14	45.0	50.0	55.0	59.0	56.0	53.0
C_4	Seconds	21	40.0	45.5	47.0	49.0	46.0	45.5
C_5		27	37.0	46.0	47.5	49.0	50.0	45.9
	Average		44.7	49.5	52.0	54.8	52.4	
C_1		1	62.5	68.0	67.5	68.0	65.0	66.2
C_2	A_5	12	45.0	48.0	48.0	49.0	48.0	47.6
C_3	Ninety	15	44.0	43.0	47.0	46.0	46.0	45.2
C_4	Seconds	24	40.0	41.0	42.5	46.0	40.0	41.9
C_5		25	38.0	39.0	37.0	41.0	39.0	38.8
	Average		45.9	47.8	48.4	50.0	47.6	

(continued)

Table 1: (Continued)

Block	Treatment	Subject	B_1 Initial	B_2 1 wk.	B_3 2 wk.	B_4 3 wk.	B_5 Retention	Average
C_1 High		6	51.5	53.0	52.0	54.0	53.0	52.7
C_2	A_6	7	48.0	54.0	56.0	60.0	56.0	54.8
C_3	120	16	44.0	45.0	46.5	50.0	48.0	46.7
C_4	Seconds	20	41.0	40.0	43.0	45.0	43.0	42.4
C_5 Low		28	37.0	40.0	43.0	45.0	38.0	40.6
	Average		44.3	46.4	48.1	50.8	47.6	

Table 2: Analysis of Variance Table

Source	Sum of Squares	D.F.	Mean Square	F Ratios
A	933.72827	5	186.74565	70.10547*
B	517.98999	4	129.49750	48.61415*
C	5025.5547	4	1256.3887	471.65601*
AB	203.92999	20	10.196499	3.82783*
AC	1235.3628	20	61.768127	23.18813*
BC	87.876663	16	5.492292	2.06184
Error	213.10252	80	2.663781	

Figure 3: Means for Treatment

Conditions at Each Time Period

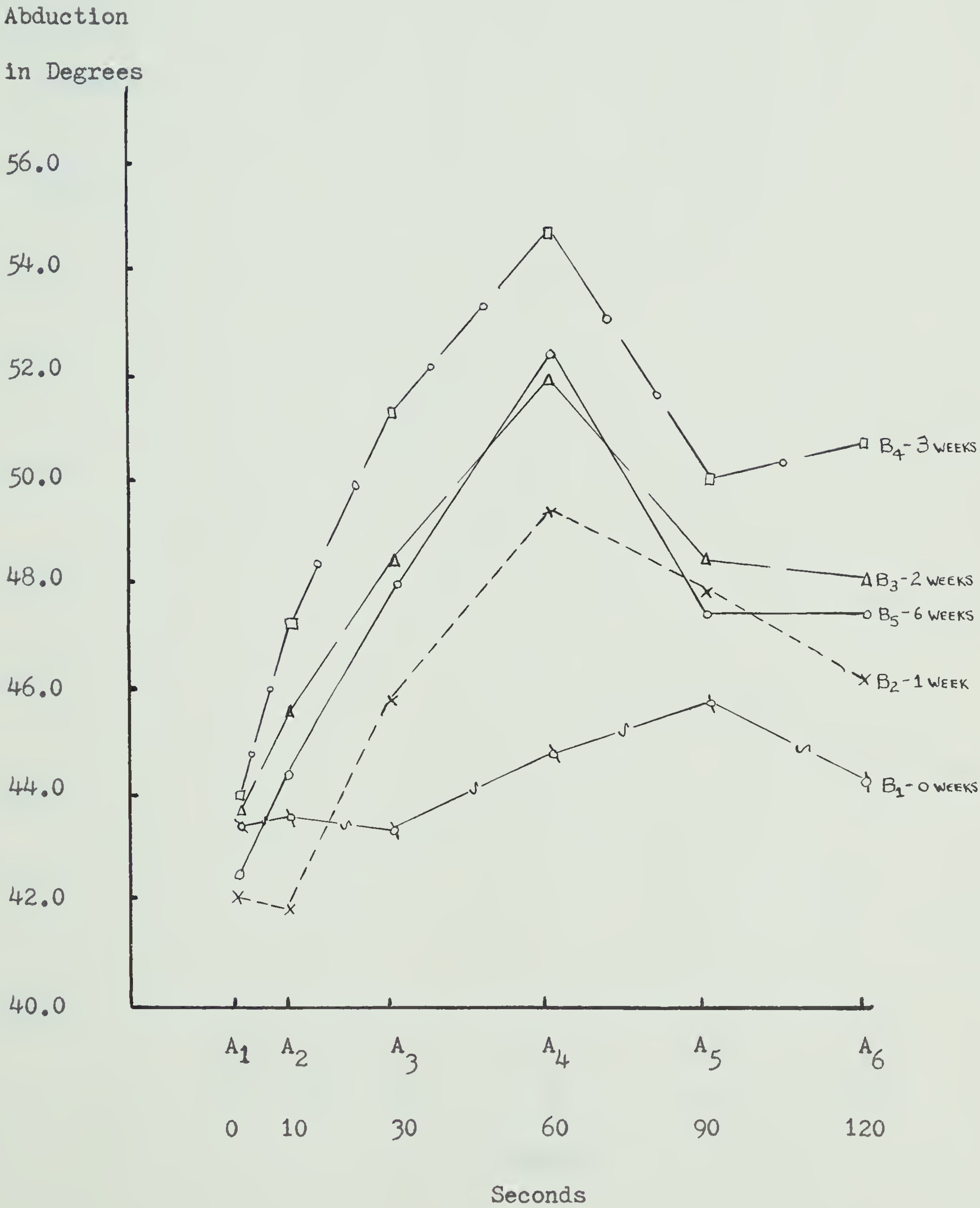


Figure 3a: Means for Treatment

Conditions at Three Time Periods

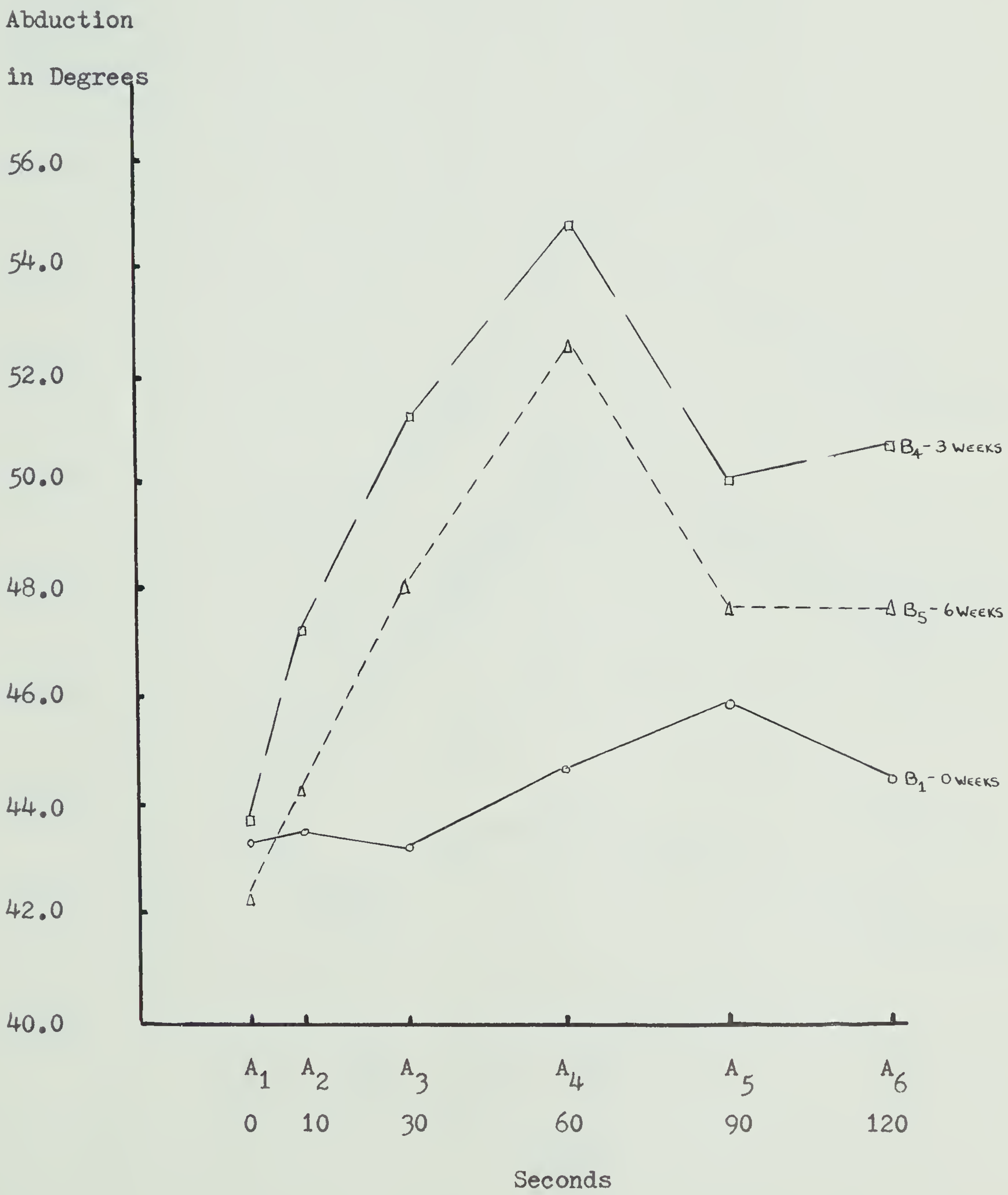


Figure 4: Means for Each Time Period at Each Treatment Condition

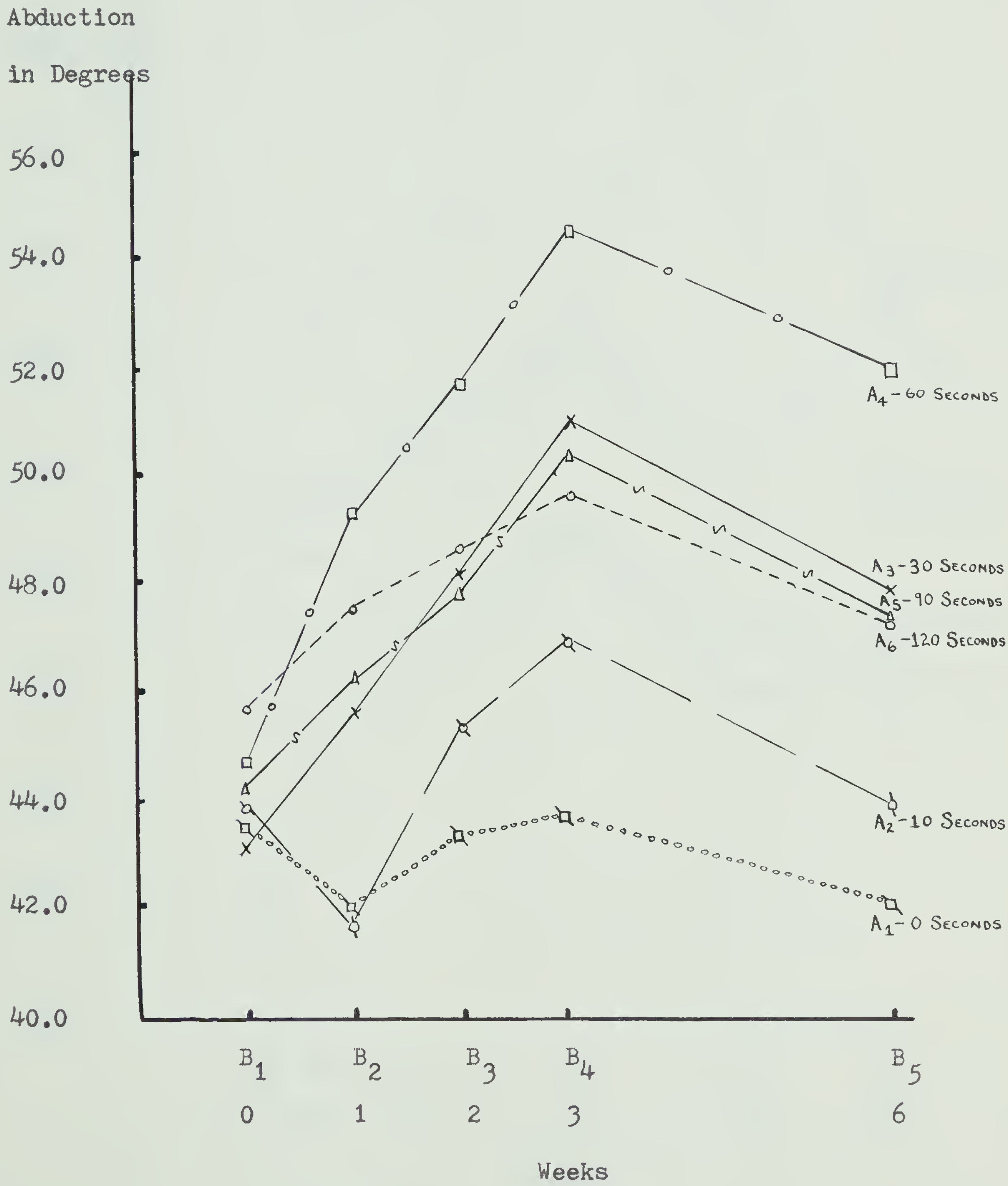


Figure 5: Means for Treatment Conditions

at Each Initial Level of Flexibility (Blocks)

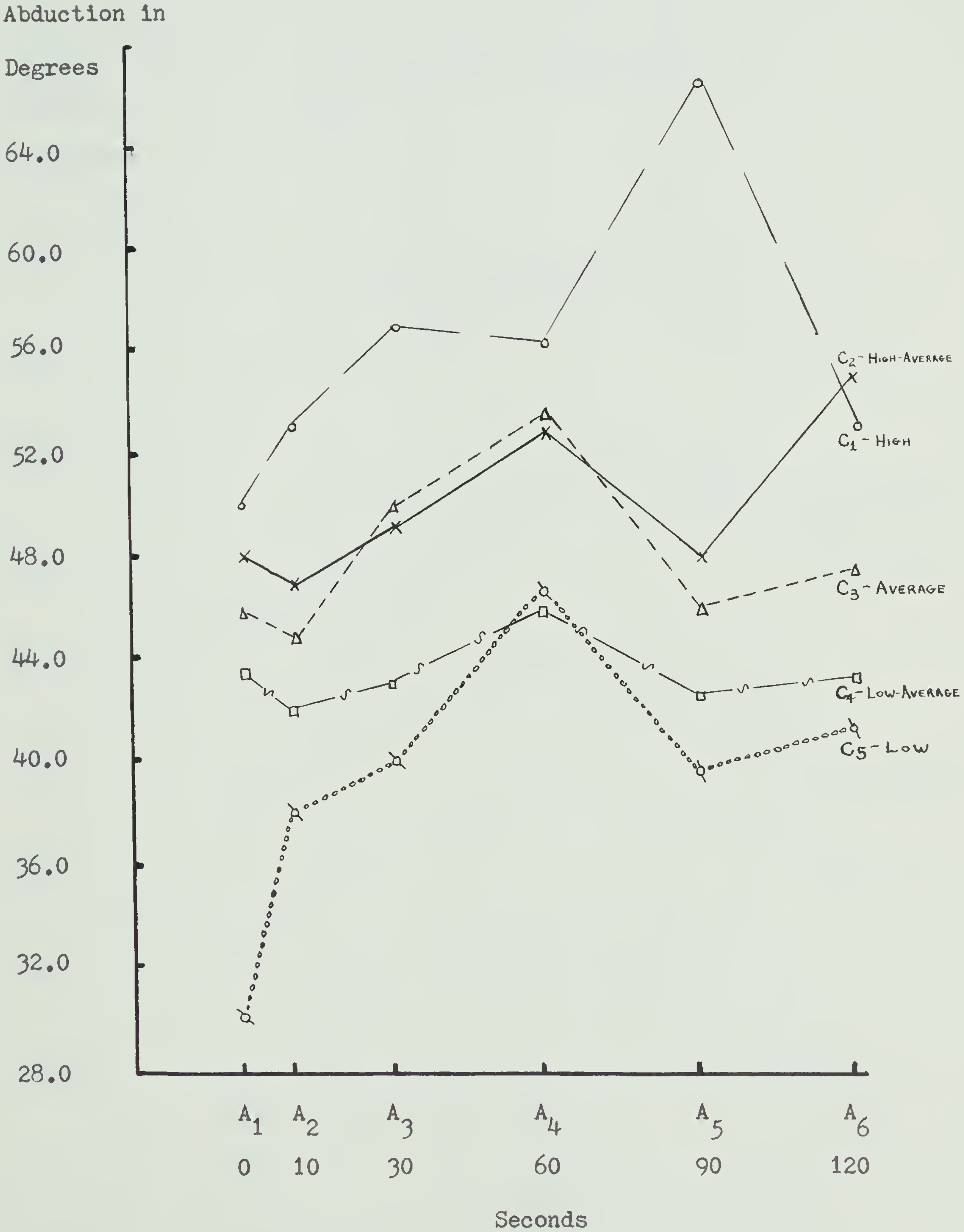


Figure 6: Means for Each Time Period at Each Initial Level of Flexibility (Blocks)

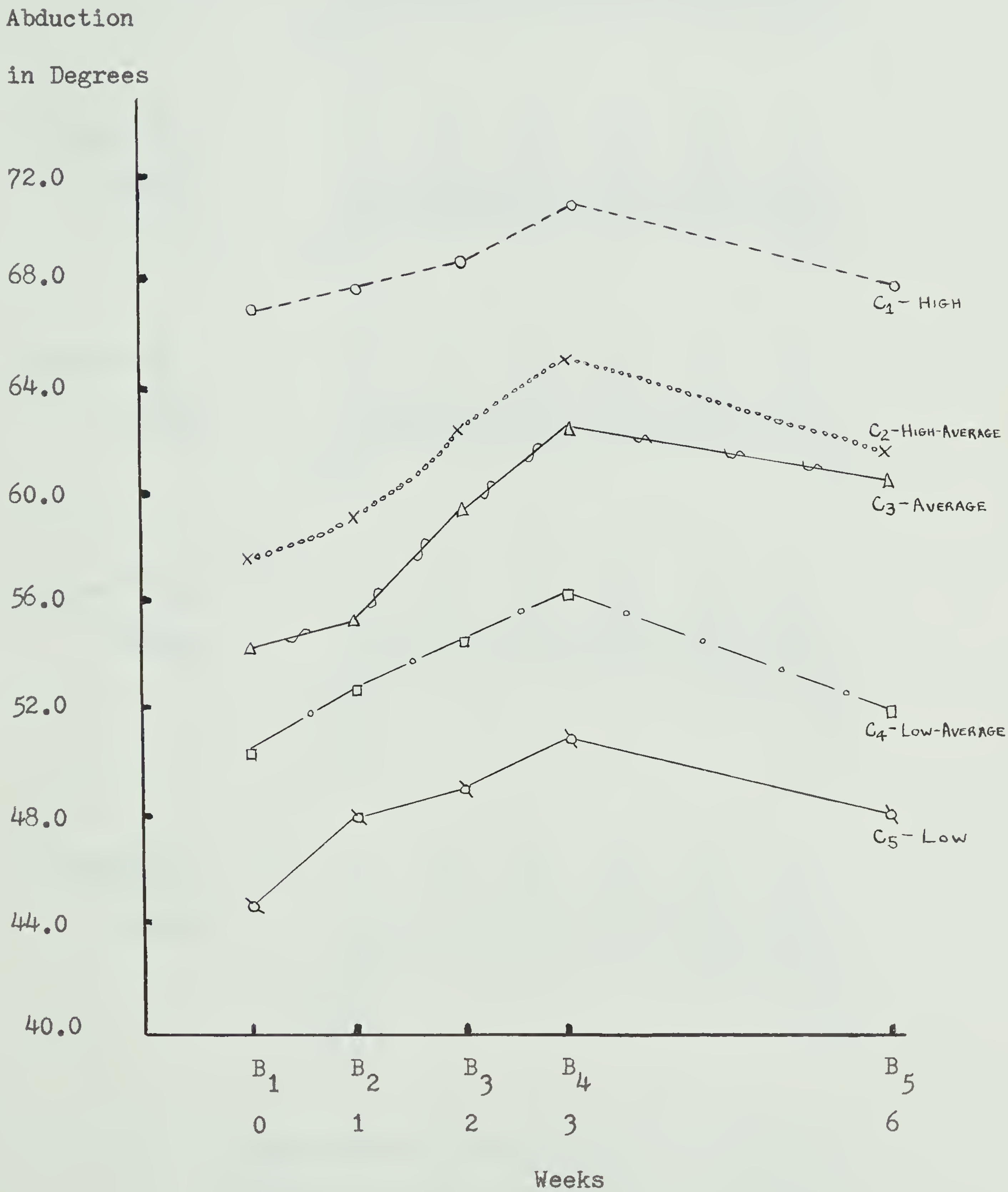


Table 3:

Differences Between Means for Treatment Conditions at Each Time Period

(a) Level B_1	A_3	A_1	A_2	A_6	A_4	A_5
Initial	43.2	43.3	43.4	44.3	44.7	45.9
A_3						2.7

(b) Level B_2	A_2	A_1	A_3	A_6	A_5	A_4
1 Week	41.9	42.0	45.9	46.4	47.8	49.5
A_2						7.6

(c) Level B_3	A_1	A_2	A_6	A_3	A_5	A_4
2 Weeks	43.5	45.5	48.1	48.3	48.4	52.0
A_1						8.5**

(d) Level B_4	A_1	A_2	A_5	A_6	A_3	A_4
3 Weeks	43.7	47.2	50.0	50.8	51.2	54.8
A_1					7.5	11.1*
A_2						7.6**

(e) Level B_5	A_1	A_2	A_5	A_6	A_3	A_4
Retention	42.3	44.2	47.6	47.6	48.0	52.4
A_1					5.7	10.1*
A_2						8.2**

* Significant at the 0.01 level of probability

** Significant at the 0.05 level of probability

Table 4:

Differences Between Means for Each Time Period at Each Treatment Condition

(a) Level A_1

Control

	B_2	B_5	B_1	B_3	B_4
	42.0	42.3	43.3	43.5	43.7
B_2					1.7

(b) Level A_2

Ten Seconds

	B_2	B_1	B_5	B_3	B_4
	41.9	43.4	44.2	45.5	47.2
B_2				3.6**	5.3*
B_1					3.8**
B_5					3.0**

(c) Level A_3

Thirty Seconds

	B_1	B_2	B_5	B_3	B_4
	43.2	45.9	48.0	48.3	51.2
B_1			4.8**	5.1**	8.0*
B_2					5.3**

(d) Level A_4

Sixty Seconds

	B_1	B_2	B_3	B_5	B_4
	44.7	49.5	52.0	52.4	54.8
B_1		4.8*	7.3*	7.7*	10.1*
B_2				2.9	5.3*
B_3					2.8

(e) Level A_5

Ninety Seconds

	B_1	B_5	B_2	B_3	B_4
	45.9	47.6	47.8	48.4	50.0
B_1				2.5	4.1*

Table 4: Continued

(e) Level A_5

Ninety Seconds

	B_1	B_5	B_2	B_3	B_4
	45.9	47.6	47.8	48.4	50.0
B_5					2.4

(f) Level A_6

120 Seconds

	B_1	B_2	B_5	B_3	B_4
	44.3	46.4	47.6	48.1	50.8
B_1				3.8	6.5*
B_2					4.4

* Significant at the 0.01 level of probability

** Significant at the 0.05 level of probability

Table 5:

Differences Between Means for Treatment Conditions at Each Initial Level of Flexibility (Blocks)

(a) Level C_1 High

	A_1	A_2	A_6	A_4	A_3	A_5
	49.6	52.4	52.7	56.1	56.6	66.2
A_1			3.1**	6.5*	7.0*	16.6*
A_2				3.7**	4.2*	13.8*
A_6				3.4**	3.9*	13.5*
A_4					0.5	10.1*
A_3						9.6*

(b) Level C_2 High-Average

	A_2	A_1	A_5	A_3	A_4	A_6
	46.3	47.4	47.6	48.7	52.9	54.8
A_2				2.4	6.6*	8.5*
A_1					5.5*	7.4*
A_5					5.3*	7.2*
A_3					4.2*	6.1*
A_4						1.9

(c) Level C_3 Average

	A_2	A_5	A_1	A_6	A_3	A_4
	44.1	45.2	45.5	46.7	49.4	53.0
A_2					5.3**	8.9*
A_5						7.8*
A_1						7.5*
A_6						6.3*
A_3						3.6**

Table 5: Continued

(d) Level C_4

Low-Average	A_2 41.6	A_5 41.9	A_3 42.2	A_6 42.4	A_1 42.8	A_4 45.5
A_2					1.2	3.9*
A_5						3.6*
A_3						3.3*
A_6						3.1*
A_1						2.7*

(e) Level C_5

Low	A_1 29.5	A_2 37.8	A_5 38.8	A_3 39.7	A_6 40.6	A_4 45.9
A_1		5.7*	6.7*	9.8*	11.1*	16.4*
A_2					2.8	11.1*
A_5						7.1*
A_3						6.2*
A_6						5.3*

* Significant at the 0.01 level of probability

** Significant at the 0.05 level of probability

Findings of the Study

Levels of B for A_1 to A_6. (a) There was a significant difference at the 0.01 level of probability between the sixty second training group and the control group after three weeks of training and this difference was maintained after three weeks without training.

(b) There was a significant difference at the 0.05 level of probability between the sixty second training group and the control group after two weeks of training, and between the ten second group after three weeks of training. This difference between the sixty second group and the ten second group was maintained after three weeks without training. Thus the first and second hypotheses were rejected.

(c) No significant difference was obtained between the ten, thirty, ninety, and 120 second groups and the control group either during the training or retention parts of the study.

(d) The order of importance for gaining flexibility and for retaining it was: sixty*#, thirty, 120, ninety, ten, and zero seconds (*significantly different from zero seconds at the 0.01 level; # significantly different from ten seconds at the 0.05 level).

Levels of A for B_1 to B_5. (a) No significant change in flexibility occurred for the control group over the six weeks of testing.

(b) The ten second training group gained significantly in flexibility at the 0.01 level of probability over the first week of training by the end of the third week of training, but not over the initial level (see discussion). At the 0.05 level there was a difference between three weeks of training and either the initial level or

retention. The second week of training was also significantly different from the first week of training at the 0.05 level (see discussion for interpretation of these results).

(c) The thirty second training group gained significantly in flexibility at the 0.01 level of probability over the initial level by the end of the third week of training. At the 0.05 level there was a difference between the third week and the first week, between the second week and the initial, and between the retention level and the initial level.

(d) The sixty second training group gained significantly in flexibility at the 0.01 level of probability over the initial level at the end of the first, second, third, and sixth weeks. The third week of training was also significantly different from the first week at the 0.01 level of probability.

(e) The ninety second training group gained significantly in flexibility at the 0.01 level of probability over the initial level by the end of the third week of training.

(f) The 120 second training group gained significantly in flexibility at the 0.01 level of probability over the initial level by the end of the third week of training.

Thus the third hypothesis was rejected on the basis of the significant gains made each week by the sixty second training group.

Levels of A for C_1 to C_5. (a) For subjects high in initial flexibility the ninety seconds of training was significantly different from all other groups at the 0.01 level of probability; however, these results may be questionable (see discussion). The

thirty seconds of training was significantly different from the control, ten, and 120 seconds at the 0.01 level; and the sixty seconds of training was significantly different from the control at the 0.01 level, and the ten and 120 seconds at the 0.05 level. The 120 seconds of training was significantly different from the control group at the 0.05 level, but the ten seconds group was not.

(b) For subjects high-average in initial flexibility the 120 seconds of training was significantly different at the 0.01 level of probability from the control, ten, thirty, and ninety seconds of training. The sixty seconds of training was significantly different at the 0.01 level from the control, ten, thiry, and ninety seconds of training. The ten, thirty, and ninety seconds of training were not significantly different from the control group.

(c) For subjects average in initial flexibility (approximately 42-45 degrees) the sixty seconds of training was significantly different at the 0.01 level of probability from the control, ten, ninety, and 120 seconds and from the thirty seconds at the 0.05 level. The thirty seconds of training was significantly different at the 0.05 level from the ten seconds of training. The ten, ninety, and 120 seconds were not significantly different from the control group.

(d) For subjects low-average in flexibility initially the sixty seconds of training was significantly different at the 0.01 level from all other groups. No other groups were significantly different from the control group.

(e) For subjects low in initial flexibility the sixty seconds of training was significantly different at the 0.01 level from all other groups. All other groups were significantly different at the

0.01 level from the control group (see discussion).

Thus the sixty seconds of training has a significant advantage at the 0.01 level over the other groups at most levels of initial flexibility, giving further support for the rejection of the first hypothesis.

CHAPTER V

CONCLUSIONS

Discussion and Recommendations

The most interesting section of this study was thought to be contained in the differences between times actually spent in a position of maximal stretch over a three week training period and a three week retention period. No studies could be found in the literature investigating this relationship and thus the fact that differences were found between training groups was an important discovery. Averaged over all levels of initial flexibility, the sixty seconds training group gained more flexibility, gained it faster, and retained more than any other group (Figure IIIa). Thus without taking into account an individual's initial level of flexibility it could be generally said that sixty seconds of holding a stretch position would give the most improvement.

The sixty second group spent half as much total time in the stretch position as did the 120 second group or two-thirds as much time as did the ninety second group and still outperformed them. However, the sixty second group spent twice as much time in the stretch position as did the thirty second group and six times as much time as did the ten second group. Even though the sixty second group outperformed them, it is still necessary to do a repeated experiment holding total time constant over a three week period and observing the improvements in flexibility between ten, thirty, and sixty seconds of training. From the present study, the relationship between time actually spent in a stretch position and gains in flexibility had

an inverted "U" shape when plotted graphically; sixty seconds being at the peak of the inverted "U" (Figures 3 and 3a). If holding the total time spent in a stretch position constant produces the same results then a definite relationship could be stated about the nature of flexibility gains.

In the findings of the study, levels of A for B_1 to B_5 (p. 27), the ten second group didn't gain flexibility significantly, at the 0.01 level, over the initial level after three weeks of training. However, they did gain significantly over the first week, which appeared confusing. Examination of the mean scores for the initial and end of the first week showed that the ten second group had dropped in flexibility from its initial level, and that this was a general drop for most individuals in the group. It was not certain whether this drop was the result of experimental error in measuring flexibility, whether the activity of the subjects outside the study had affected them, or whether it was the result of the treatment condition (ten seconds of training). Some suggestions for future studies would help isolate the cause of such a variation: (a) three measurements could be recorded for each subject on each test day (giving an estimate of experimental error in the analysis of variance) (b) three to ten subjects could be included in every block at each treatment condition (giving a better estimate of the effect of the activity); (c) conducting the training over a longer period of weeks (giving a better estimate on the nature of the effect of the treatment and reducing the effect of outside activity).

The last suggestion of conducting the experiment over a

longer period of weeks would prove interesting in examining the nature of the rate of gaining flexibility, the plateaus which may occur, and also the rate of loss. From the present study it was shown that the different treatment times represented different rates of gaining flexibility (sixty seconds best) and that all groups took three weeks to lose approximately what they had gained between the second and third week of training. The ten second group appeared to lose the most flexibility, dropping close to the initial level. Thus if an individual is interested in retention of the flexibility gained he should train for sixty seconds (significant at the 0.01 level, p. 28).

Examination of the results under levels of A for C_1 to C_5 (p.28) found that for subjects high in initial flexibility ninety seconds appeared best at the 0.01 level for gaining flexibility. However, caution must be used here since each treatment had only one subject from a particular block (in this case, high flexibility). The ninety seconds appeared best in this case since the subject in the ninety second group was initially nine degrees higher than all others in his block. The recommendation for future studies would be to eliminate such individuals from an otherwise homogenous block. A similar problem exists in the low block (p.29) with the subject in the control group being six degrees lower than all others in his block to start with. This does not represent as important a problem since he was in the control group. However, the results should be interpreted for that level that only the sixty seconds of training was significantly different from the other groups.

Interpreting the results of levels of A for C_1 to C_5 would

indicate that sixty seconds of training is significantly better for gaining flexibility (at the 0.01 level) for individuals low, low-average, average, and high average in initial flexibility. The thirty seconds of training appears to become important for individuals high in initial flexibility. Although there was no significant difference between thirty and sixty seconds for individuals high in initial flexibility it was assumed that individuals would choose the shortest training time to gain the same flexibility. There appeared to be a relationship between initial level of flexibility and the training time needed to increase flexibility, which warrants further study, that is, as individuals increase in flexibility it is possible that they need to spend less time in a stretch position.

One additional point is worth noting. Leighton (32) found a sample of fifty-six college students to average 54.6 degrees, with a standard deviation of 7.8 degrees, in left leg abduction, whereas in the present study the average initially was 44.2 degrees, with a standard deviation of 6.5 degrees. It is possible that the sample in this study is lower in flexibility than normal and that the results obtained would not be as applicable to samples of higher initial flexibility. Another study could be called for involving groups initially high to very high in flexibility.

Conclusions

The following three hypotheses were tested for significance at the 0.01 level of probability and were rejected.

1. There is no difference in flexibility gains as a result of the increasing time a side splits position is held.

2. There is no difference in the retention of flexibility gains between groups maintaining a side splits position for increasing lengths of time.

3. There is no difference in the rate of gaining flexibility as a result of the increasing time a side splits position is held.

It was found that the group of subjects using sixty seconds of training to increase flexibility gained more flexibility, retained more flexibility, and gained flexibility faster.

It was also found that by taking initial level of flexibility into account sixty seconds of training produced a greater increase in flexibility over any other group for those low, low-average, average, and high-average in initial flexibility. For those high in initial flexibility there was no significant difference between the gains produced by thirty or sixty seconds of training.

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APPENDIX 1

SUBJECT'S APPAREL

In order to facilitate training for the side splits, it was necessary that two conditions be met. The subject's leg abduction must have been as unrestricted as possible, thus bikini-type swimming trunks were chosen in place of regular gym shorts. The regular gym shorts can restrict movement as the range of motion increases. Secondly, friction between the subject's feet and the floor can prevent the maximum range of motion from being achieved. Thus a relatively smooth surfaced tiled floor was used with thick wool socks on the subject's feet.

APPENDIX 2

TRAINING INSTRUCTIONS

The following instructions were given to all subjects before the pre-test and during training as required. The control on the occasion of the tests would follow all instructions as the other groups did.

1. Assume the initial starting position as follows:

(a) While standing, place your feet on the outlined feet on the tiled floor (toes pointing out at 45 degrees to account for leg rotation in doing the side splits).

(b) Grasp the supporting pole with both hands, at a comfortable height, approximately waist height.

(c) Your legs should be straight now, and remain straight throughout the training session.

(d) Your back is upright, with your hips in line with your feet and this posture should remain the same throughout the training session.

2. Proceed to stretch for the required time (t= 10, 30, 60, 90, 120 seconds) according to these instructions:

(a) Slowly and with control allow your feet to slide directly to each side as far as possible (a scale marked in inches was provided for guidance of the feet).

(b) Your hands should slide down the pole as your feet slide apart.

(c) Be very careful to maintain your back in an upright position and keep your hips in line with your feet and trunk. Do not allow your hips to move backwards or forwards of this vertical plane.

(d) When the position of maximal stretch is reached try to relax. This will allow the feet to slide further apart. Try not to resist this action.

(e) Should you experience pain which prevents you from relaxing, you may take a slight amount of pressure from the feet by pulling with the hands on the pole. Do not take a large amount of weight off the feet and do not hold the weight off for a long period of time. When the pain subsides allow the weight to again go on the feet.

3. As needed during training the following instructions were given:

(a) Check your body position. Make sure your back is upright, your hips are in line, and that you are not maintaining weight on your hands.

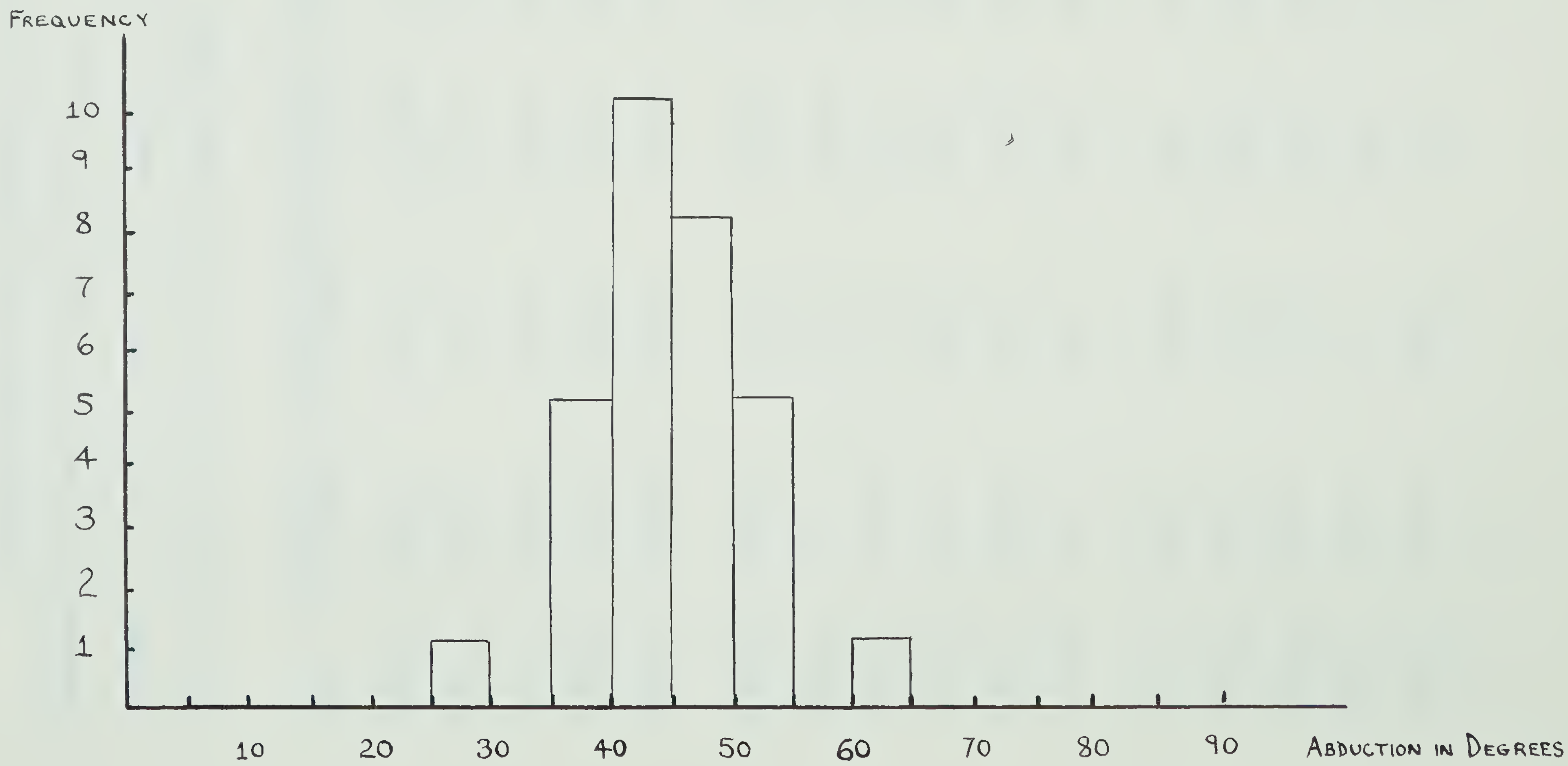
(b) Consciously relax and allow the feet to slide apart.

APPENDIX 3

BLOCKING OF SUBJECTS

Subject	Pre-Test (Degrees)	Treatment	Block
1	62.5	5	1
2	54.0	4	1
3	53.0	3	1
4	53.0	2	1
5	52.0	1	1
6	51.5	6	1
7	48.0	6	2
8	48.0	1	2
9	47.5	4	2
10	46.0	2	2
11	45.0	3	2
12	45.0	5	2
13	45.0	1	3
14	45.0	4	3
15	44.0	5	3
16	44.0	6	3
17	42.0	2	3
18	42.0	3	3
19	42.0	1	4
20	41.0	6	4
21	40.0	4	4
22	40.0	3	4
23	40.0	2	4
24	40.0	5	4
25	38.0	5	5
26	37.5	2	5
27	37.0	4	5
28	37.0	6	5
29	36.0	3	5
30	29.5	1	5

FREQUENCY DISTRIBUTION OF INITIAL FLEXIBILITY SCORES



APPENDIX 4

CALCULATION OF MS_{error} for AxB, BxA, CxA

For each level of one factor, A_{1-6} for example, it was necessary to obtain the total sum of squares, the treatment sum of suqares, the second factor sum of squares, B_1 for example, the error sum of squares, and thus the error mean square (15, p.169).

Level	Total Sum of Squares	Treatment Sum of Squares	Block Sum of Squares	Error Sum of Squares	D.F.	MS_{error}
B_1xA_{1-6}	1333.47	27.87	1179.38	126.22	20	6.3
B_2xA_{1-6}	1539.54	237.14	942.08	360.32	20	18.02
B_3xA_{1-6}	1498.47	209.77	960.97	327.73	20	16.39
B_4xA_{1-6}	1691.84	358.84	996.47	336.53	20	16.83
B_5xA_{1-6}	1636.24	304.04	1034.53	297.67	20	14.88
A_1xB_{1-5}	1287.96	11.56	1257.26	19.14	16	1.2
A_2xB_{1-5}	728.16	81.66	595.46	51.04	16	3.19
A_3xB_{1-5}	1140.94	177.34	883.14	80.46	16	5.03
A_4xB_{1-5}	807.44	294.14	446.84	66.46	16	4.15
A_5xB_{1-5}	2382.66	43.76	2305.36	37.54	16	2.35
A_6xB_{1-5}	936.66	65.41	772.86	98.39	16	6.15
C_1xA_{1-6}	946.20	841.30	38.87	66.03	20	3.30
C_2xA_{1-6}	529.35	292.35	153.39	83.61	20	4.18
C_3xA_{1-6}	643.74	275.74	229.53	138.47	20	6.92
C_4xA_{1-6}	168.37	50.17	82.95	35.25	20	1.76
C_5xA_{1-6}	874.09	709.54	101.13	63.42	20	3.17

APPENDIX 5

CALCULATION OF $S_{\bar{x}}$ AND $S_{\bar{x}}q_{.01}(r_{2-6}, d.f._{error})$

The standard error of a single mean $S_{\bar{x}}$ was calculated using the values obtained in Appendix 4.

$S_{\bar{x}} = MS_{error}/ n$ where n equals the number of observations on which the mean is based

$q_{.01}(r_{2-6}, d.f._{error})$ values were obtained from Winer (46, p.648).

Level	MS_{error}	n	$S_{\bar{x}}$	$S_{\bar{x}}q_{.01}$ r=2	$S_{\bar{x}}q_{.01}$ r=3	$S_{\bar{x}}q_{.01}$ r=4	$S_{\bar{x}}q_{.01}$ r=5	$S_{\bar{x}}q_{.01}$ r=6
B_1xA_{1-6}	2.51	2.24	1.12	4.50	5.20	5.62	5.92	6.17
B_2xA_{1-6}	4.24	2.24	1.89	7.60	8.77	9.49	9.99	10.41
B_3xA_{1-6}	4.05	2.24	1.81	7.27	8.40	9.09	9.57	9.97
B_4xA_{1-6}	4.10	2.24	1.83	7.36	8.49	9.19	9.68	10.10
B_5xA_{1-6}	3.86	2.24	1.72	6.91	7.89	8.63	9.10	9.48
A_1xB_{1-5}	1.10	2.24	0.49	2.02	2.34	2.54	2.69	
A_2xB_{1-5}	1.79	2.24	0.80	3.30	3.82	4.15	4.39	
A_3xB_{1-5}	2.24	2.24	1.00	4.13	4.78	5.19	5.49	
A_4xB_{1-5}	2.04	2.24	0.91	3.76	4.35	4.72	5.00	
A_5xB_{1-5}	1.53	2.24	0.69	2.85	3.30	3.58	3.79	
A_6xB_{1-5}	2.48	2.24	1.11	4.58	5.31	5.76	6.09	
C_1xA_{1-6}	1.82	2.24	0.81	3.25	3.76	4.07	4.28	4.46
C_2xA_{1-6}	2.04	2.24	0.91	3.66	4.22	4.57	4.81	5.01
C_3xA_{1-6}	2.63	2.24	1.17	4.70	5.43	5.87	6.19	6.45
C_4xA_{1-6}	1.33	2.24	0.59	2.37	2.74	2.96	3.12	3.25
C_5xA_{1-6}	1.78	2.24	0.79	3.18	3.67	3.97	4.18	4.35